

Harleen Dahiya and Manmohan Gupta

Department of Physics, Centre of Advanced Study in Physics, Panjab University, Chandigarh-160 014, India.

(April 21, 2003)

Octet and decuplet baryon magnetic moments have been formulated within the chiral quark model (χ QM) with configuration mixing incorporating the sea quark polarizations and their orbital angular momentum through the generalization of the Cheng-Li mechanism. When the parameters of χ QM without configuration mixing are fixed by incorporating the latest data pertaining to $\bar{u} - \bar{d}$ asymmetry (E866) and the spin polarization functions, in the case of octet magnetic moments the results not only show improvement over the nonrelativistic quark model results but also give a non zero value for the right hand side of Coleman-Glashow sum rule, usually zero in most of the models. In the case of decuplet magnetic moments, we obtain a good overlap for Δ^{++} , Ω^- and the transition magnetic moment ΔN for which data are available. In the case of octet, the predictions of the χ QM with the generalized Cheng-Li mechanism show remarkable improvements in general when effects of configuration mixing and “mass adjustments” due to confinement are included, specifically in the case of p , Σ^+ , Ξ^0 , the $\Sigma\Lambda$ transition magnetic moment and in the violation of Coleman Glashow sum rule an almost perfect agreement with data is obtained. When the above analysis is repeated with the earlier NMC data, a similar level of agreement is obtained, however the results in the case of E866 look to be better. In case, we incorporate in our analysis the gluon polarization Δg , found phenomenologically through the relation $\Delta\Sigma(Q^2) = \Delta\Sigma - \frac{3\alpha_s(Q^2)}{2\pi}\Delta g(Q^2)$, we not only obtain improvement in the quark spin distribution functions and magnetic moments but also the value of Δg comes out to be in good agreement with certain recent measurements as well as theoretical estimates.

I. INTRODUCTION

The measurements of the polarized structure functions of proton in the deep inelastic scattering (DIS) experiments [1–3] have shown that the valence quarks of the proton carry only about 30% of its spin. This “unexpected” conclusion from the point of view of nonrelativistic quark model (NRQM) becomes all the more intriguing when it is realized that the NRQM is able to give a reasonably good description of baryon octet magnetic moments using the assumption that magnetic moments of quarks are proportional to the spin carried by them. Further, this issue regarding spin and magnetic moments becomes all the more difficult to understand when it is realized that the magnetic moments of baryons receive contributions not only from the magnetic moments carried by the valence quarks but also from various complicated effects, such as orbital excitations [4], relativistic and exchange current effects [5,6], pion cloud contributions [7], effect of the confinement on quark masses [8,9], effects of configuration mixing [5,9,10], “quark sea” polarizations [11–15], pion loop corrections [16], etc.. Recently, it has been emphasized [15,17] that the problem regarding magnetic moments gets further complicated when one realizes that the Coleman Glashow sum rule (CGSR) for octet magnetic moments [18], valid in a large variety of models, is convincingly violated by the data [19].

Recently, in a very interesting work, Cheng and Li [13] have shown that the DIS conclusions regarding the proton spin and the success of the NRQM in explaining magnetic moments can be reconciled in the χ QM [11,21–23] if the $q\bar{q}$ sea, produced by the chiral fluctuations, besides being polarized is also endowed with angular momentum. In particular, in the case of the nucleon they have shown that the above mentioned mechanism (to be referred to as Cheng-Li mechanism) leads to almost cancellations of the magnetic moment contribution of the polarized “quark sea” and its angular momentum leaving the description of magnetic moment of nucleon in terms of the polarization of the valence quarks. The authors, in a very recent Rapid Communication [20], by considering the generalization of the Cheng-Li mechanism to hyperons incorporating coupling breaking and mass breaking terms, found that one is able to get a non zero value for the violation of CGSR (ΔCG) [24] apart from improving the NRQM predictions for magnetic moments of the octet baryons. This fact, when viewed in the context of success of χ QM [11–15,23], for the explanation of $\bar{u} - \bar{d}$ asymmetry [25–27], existence of significant strange quark content [1–3], quark flavor and spin distribution functions [2], hyperon decay parameters etc., strongly indicates that constituent quarks, weakly interacting Goldstone bosons (GBs) and $q\bar{q}$ pairs provide the appropriate degrees of freedom at the leading order in the scale between chiral symmetry breaking (χ_{SB}) and the confinement scale. This is further borne out by the fact that when the generalized Cheng-Li mechanism is combined with the effects of configuration mixing, known to be improving the predictions of NRQM [5,10,28–30] as well as compatible [31–33] with χ QM, and “mass adjustments” arising due to confinement of quarks [8,9], leads to an almost perfect fit for ΔCG and an excellent fit for octet magnetic moments [20]. In view

of this, it is desirable to broaden the scope of Ref [20] by extending the calculations to decuplet magnetic moments, transition magnetic moments and by delving into the detailed implications of some of the crucial ingredients such as the generalized Cheng-Li mechanism (with and without configuration mixing) and “mass adjustments” on the octet magnetic moments, not detailed in Ref [20]. At the same time, for an appropriate appraisal of the implications of the calculated magnetic moments, it is desirable to fine tune the χ QM parameters by analysing the latest data pertaining to $\bar{u} - \bar{d}$ asymmetry [26], spin polarization functions [2] as well as the flavor non-singlet components.

The purpose of the present paper is to detail the formulation of the octet and decuplet magnetic moments in χ QM incorporating the generalized Cheng-Li mechanism (with and without configuration mixing). In order to make our analysis regarding magnetic moments more responsive, we have carried out a brief analysis to fix the χ QM parameters using the latest data regarding the quark distribution functions and spin distribution functions. A brief discussion on the flavor singlet component of the total helicity including gluon polarization and its implications on the magnetic moments is also very much in order. Further, we also intend to study the implications of variation of quark masses as well as the angle pertaining to configuration mixing on magnetic moments.

The plan of the paper is as follows. To make the manuscript readable as well as to facilitate discussion, in Sec II we present some of the essentials of χ QM and Cheng-Li mechanism with an emphasis on the details of its generalization. In Sec III, the modifications due to configuration mixing on the generalized Cheng-Li mechanism have been discussed. Sec IV includes a discussion on the various inputs used in the analysis, in particular the χ QM parameters have been obtained by fitting χ QM with and without configuration mixing to the latest data. In Sec V, we present the numerical results and their discussion including a brief reference to the flavor singlet component as well as gluon polarization. Sec VI comprises the summary and the conclusions. To make the manuscript self contained, in the Appendix a few typical cases pertaining to octet as well as decuplet baryons have been fully worked out.

II. MAGNETIC MOMENTS IN THE χ QM WITH THE GENERALIZED CHENG-LI MECHANISM

The basic process in the χ QM is the emission of a GB by a constituent quark which further splits into a $q\bar{q}$ pair, for example,

$$q_{\pm} \rightarrow \text{GB}^0 + q'_{\mp} \rightarrow (q\bar{q}') + q'_{\mp}, \quad (1)$$

where $q\bar{q}' + q'$ constitute the “quark sea” [12–15]. The effective Lagrangian describing interaction between quarks and a nonet of GBs, consisting of octet and a singlet, can be expressed as

$$\mathcal{L} = g_8 \bar{q} \Phi q, \quad (2)$$

$$q = \begin{pmatrix} u \\ d \\ s \end{pmatrix}, \quad \Phi = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \beta \frac{\eta}{\sqrt{6}} + \zeta \frac{\eta'}{\sqrt{3}} & \pi^+ & \alpha K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \beta \frac{\eta}{\sqrt{6}} + \zeta \frac{\eta'}{\sqrt{3}} & \alpha K^0 \\ \alpha K^- & \alpha \bar{K}^0 & -\beta \frac{2\eta}{\sqrt{6}} + \zeta \frac{\eta'}{\sqrt{3}} \end{pmatrix}, \quad (3)$$

where $\zeta = g_1/g_8$, g_1 and g_8 are the coupling constants for the singlet and octet GBs, respectively.

SU(3) symmetry breaking is introduced by considering $M_s > M_{u,d}$ as well as by considering the masses of GBs to be nondegenerate ($M_{K,\eta} > M_{\pi}$) [12–15], whereas the axial U(1) breaking is introduced by $M_{\eta'} > M_{K,\eta}$ [11–15]. The parameter $a (= |g_8|^2)$ denotes the transition probability of chiral fluctuation of the splittings $u(d) \rightarrow d(u) + \pi^{+(-)}$, whereas $\alpha^2 a$, $\beta^2 a$ and $\zeta^2 a$ respectively denote the probabilities of transitions of $u(d) \rightarrow s + K^{-(o)}$, $u(d, s) \rightarrow u(d, s) + \eta$, and $u(d, s) \rightarrow u(d, s) + \eta'$.

Following Cheng and Li [13], the magnetic moment of a given baryon which receives contributions from valence quarks, sea quarks and the orbital angular momentum of the “quark sea” is expressed as

$$\mu(B)_{\text{total}} = \mu(B)_{\text{val}} + \mu(B)_{\text{sea}} + \mu(B)_{\text{orbit}}. \quad (4)$$

The valence and the sea contributions, in terms of quark spin polarizations, can be written as

$$\mu(B)_{\text{val}} = \sum_{q=u,d,s} \Delta q_{\text{val}} \mu_q \quad \text{and} \quad \mu(B)_{\text{sea}} = \sum_{q=u,d,s} \Delta q_{\text{sea}} \mu_q, \quad (5)$$

where $\mu_q = \frac{e_q}{2M_q}$ ($q = u, d, s$) is the quark magnetic moment, e_q and M_q are the electric charge and the mass respectively for the quark q . Similarly, the orbital angular momentum contribution of the sea, $\mu(B)_{\text{orbit}}$, can be

expressed in terms of the valence quark polarizations and the orbital moments of the sea quarks, the details of which would be given in Section II B. Following references [11,13,15], the quark spin polarization can be defined as

$$\Delta q = q_+ - q_- + \bar{q}_+ - \bar{q}_-, \quad (6)$$

where q_\pm and \bar{q}_\pm can be calculated from the spin structure of a baryon defined as

$$\hat{B} \equiv \langle B | \mathcal{N} | \mathcal{B} \rangle, \quad (7)$$

where $|B\rangle$ is the baryon wave function and \mathcal{N} is the number operator, for example,

$$\mathcal{N} = n_{u+} u_+ + n_{u-} u_- + n_{d+} d_+ + n_{d-} d_- + n_{s+} s_+ + n_{s-} s_-, \quad (8)$$

with the coefficients of the q_\pm giving the number of q_\pm quarks.

To calculate $\mu(B)_{\text{val}}$, we need to calculate the valence spin polarizations Δq_{val} . For ready reference some essential details of the calculations for valence quark polarizations pertaining to typical cases are presented in Appendix A.

A. Contribution of the “quark sea” polarizations to the magnetic moments

To evaluate the “quark sea” magnetic moment, one has to find Δq_{sea} corresponding to each baryon. For detailed evaluation of Δq_{sea} , we refer the reader to Refs. [12–15], however to facilitate its extension to the case with configuration mixing, we summarize some of the essentials adopted for the present use. The spin structure for the process given in Eq. (1), after one interaction, can be obtained by substituting for every valence quark, for example,

$$q_\pm \rightarrow \sum P_q q_\pm + |\psi(q_\pm)|^2, \quad (9)$$

where $\sum P_q$ is the probability of emission of GB from a q quark and the probabilities of transforming a q_\pm quark are $|\psi(q_\pm)|^2$. The relevant details pertaining to the calculations of Δq_{sea} , again for some typical cases, are presented in Appendix A. The expressions for Δq_{sea} in the case of proton are as follows

$$\Delta u_{\text{sea}} = -\frac{a}{3}(7 + 4\alpha^2 + \frac{4}{3}\beta^2 + \frac{8}{3}\zeta^2), \quad \Delta d_{\text{sea}} = -\frac{a}{3}(2 - \alpha^2 - \frac{1}{3}\beta^2 - \frac{2}{3}\zeta^2), \quad \Delta s_{\text{sea}} = -a\alpha^2. \quad (10)$$

The expressions for the other octet baryons can be found from Table I.

The “quark sea” spin polarizations for the decuplet baryons can be calculated in a similar manner as that of octet baryons. For example, the general expressions for the spin structure of the decuplet baryons of the types $B^*(xy)$, $B^*(xxx)$ and $B^*(xyz)$, using Eq. (9), are respectively given as

$$\hat{B}^*(xy) = 2 \left(\sum P_x x_+ + |\psi(x_+)|^2 \right) + \left(\sum P_y y_+ + |\psi(y_+)|^2 \right), \quad (11)$$

$$\hat{B}^*(xxx) = 3 \left(\sum P_x x_+ + |\psi(x_+)|^2 \right), \quad (12)$$

$$\hat{B}^*(xyz) = \left(\sum P_x x_+ + |\psi(x_+)|^2 \right) + \left(\sum P_y y_+ + |\psi(y_+)|^2 \right) + \left(\sum P_z z_+ + |\psi(z_+)|^2 \right), \quad (13)$$

where x , y and z correspond to any of the u , d and s quarks. The detailed expressions for the spin polarizations Δq_{sea} , corresponding to the decuplet baryons, can again be found from Table I.

B. Contribution of the “quark sea” orbital angular momentum to the magnetic moments

Following Cheng and Li [13], the contribution of the angular momentum of the “quark sea” to the magnetic moment of a given quark is given as

$$\mu(q_+ \rightarrow q'_-) = \frac{e_{q'}}{2M_q} \langle l_q \rangle + \frac{e_q - e_{q'}}{2M_{\text{GB}}} \langle l_{\text{GB}} \rangle, \quad (14)$$

where

$$\langle l_q \rangle = \frac{M_{GB}}{M_q + M_{GB}} \text{ and } \langle l_{GB} \rangle = \frac{M_q}{M_q + M_{GB}}, \quad (15)$$

$\langle l_q, l_{GB} \rangle$ and (M_q, M_{GB}) are the orbital angular momenta and masses of quark and GB respectively. The orbital moment of each process is then multiplied by the probability for such a process to take place to yield the magnetic moment due to all the transitions starting with a given valence quark, for example,

$$[\mu(u_\pm(d_\pm) \rightarrow)] = \pm a \left[\mu(u_+(d_+) \rightarrow d_-(u_-)) + \alpha^2 \mu(u_+(d_+) \rightarrow s_-) + \left(\frac{1}{2} + \frac{1}{6}\beta^2 + \frac{1}{3}\zeta^2\right) \mu(u_+(d_+) \rightarrow u_-(d_-)) \right], \quad (16)$$

$$[\mu(s_\pm \rightarrow)] = \pm a \left[\alpha^2 \mu(s_+ \rightarrow u_-) + \alpha^2 \mu(s_+ \rightarrow d_-) + \left(\frac{2}{3}\beta^2 + \frac{1}{3}\zeta^2\right) \mu(s_+ \rightarrow s_-) \right]. \quad (17)$$

The above equations, derived by Cheng and Li, alongwith Δq_{sea} constitute the essentials of Cheng-Li mechanism. Eqs. (16) and (17) can easily be generalized by including the coupling breaking and mass breaking terms. For example, in terms of the parameters a , α , β and ζ , the orbital moments of u , d and s quarks respectively are

$$\mu(u_+ \rightarrow) = a \left[\frac{-M_\pi^2 + 3M_u^2}{2M_\pi(M_u + M_\pi)} - \frac{\alpha^2(M_K^2 - 3M_u^2)}{2M_K(M_u + M_K)} + \frac{(3 + \beta^2 + 2\zeta^2)M_\eta^2}{6M_\eta(M_u + M_\eta)} \right] \mu_N, \quad (18)$$

$$\mu(d_+ \rightarrow) = a \frac{M_u}{M_d} \left[\frac{2M_\pi^2 - 3M_d^2}{2M_\pi(M_d + M_\pi)} - \frac{\alpha^2 M_K^2}{2M_K(M_d + M_K)} - \frac{(3 + \beta^2 + 2\zeta^2)M_\eta^2}{12M_\eta(M_d + M_\eta)} \right] \mu_N, \quad (19)$$

$$\mu(s_+ \rightarrow) = a \frac{M_u}{M_s} \left[\frac{\alpha^2(M_K^2 - 3M_s^2)}{2M_K(M_s + M_K)} - \frac{(2\beta^2 + \zeta^2)M_\eta^2}{6M_\eta(M_s + M_\eta)} \right] \mu_N, \quad (20)$$

where μ_N is the nuclear magneton. Eqs. (18), (19) and (20) alongwith Δq_{sea} shall be referred to as the generalized Cheng-Li mechanism. The orbital contribution to the magnetic moment of the octet baryon of the type $B(xxy)$ in terms of the above equations as well as the valence spin polarizations is given as

$$\mu(B)_{\text{orbit}} = \Delta x_{\text{val}} [\mu(x_+ \rightarrow)] + \Delta y_{\text{val}} [\mu(y_+ \rightarrow)]. \quad (21)$$

Similarly, the orbital contributions in the case of the decuplet baryons $B^*(xxy)$, $B^*(xxx)$ and $B^*(xyz)$ are respectively given as

$$\mu(B^*)_{\text{orbit}} = \Delta x_{\text{val}} [\mu(x_+ \rightarrow)] + \Delta y_{\text{val}} [\mu(y_+ \rightarrow)], \quad (22)$$

$$\mu(B^*)_{\text{orbit}} = \Delta x_{\text{val}} [\mu(x_+ \rightarrow)], \quad (23)$$

$$\mu(B^*)_{\text{orbit}} = \Delta x_{\text{val}} [\mu(x_+ \rightarrow)] + \Delta y_{\text{val}} [\mu(y_+ \rightarrow)] + \Delta z_{\text{val}} [\mu(z_+ \rightarrow)]. \quad (24)$$

III. GENERALIZED CHENG-LI MECHANISM WITH CONFIGURATION MIXING

Spin-spin forces, known to be compatible [31–33] with the χ QM, generate configuration mixing [10,28,29] for the octet baryons which effectively leads to modification of the valence quark and “quark sea” spin distribution functions [34]. From Eqs. (5) and (21), it is evident that the effects of configuration mixing on magnetic moments can be included if one is able to estimate the same on the valence and sea contributions to magnetic moments. The most general configuration mixing generated by the spin-spin forces in the case of octet baryons [10,29,35] can be expressed as

$$|B\rangle = (|56, 0^+\rangle_{N=0} \cos \theta + |56, 0^+\rangle_{N=2} \sin \theta) \cos \phi + (|70, 0^+\rangle_{N=2} \cos \theta' + |70, 2^+\rangle_{N=2} \sin \theta') \sin \phi, \quad (25)$$

where ϕ represents the $|56\rangle - |70\rangle$ mixing whereas θ and θ' respectively correspond to the mixing among $|56, 0^+\rangle_{N=0} - |56, 0^+\rangle_{N=2}$ states and $|70, 0^+\rangle_{N=2} - |70, 2^+\rangle_{N=2}$ states. For the present purpose, it is adequate [5,9,29,34] to consider the mixing only between $|56, 0^+\rangle_{N=0}$ and the $|70, 0^+\rangle_{N=2}$ states, for example,

$$|B\rangle \equiv \left|8, \frac{1}{2}^+\right\rangle = \cos \phi |56, 0^+\rangle_{N=0} + \sin \phi |70, 0^+\rangle_{N=2}, \quad (26)$$

where

$$|56, 0^+\rangle_{N=0} = \frac{1}{\sqrt{2}}(\chi' \phi' + \chi'' \phi'') \psi^s(0^+), \quad (27)$$

$$|70, 0^+\rangle_{N=2} = \frac{1}{2}[(\phi' \chi'' + \phi'' \chi') \psi'(0^+) + (\phi' \chi' - \phi'' \chi'') \psi''(0^+)], \quad (28)$$

with

$$\chi' = \frac{1}{\sqrt{2}}(\uparrow\uparrow\uparrow - \downarrow\uparrow\uparrow), \quad \chi'' = \frac{1}{\sqrt{6}}(2\uparrow\uparrow\downarrow - \uparrow\downarrow\uparrow - \downarrow\uparrow\uparrow), \quad (29)$$

representing the spin wave functions. In general, the isospin wave functions for the octet baryons of the type $B(xxy)$ are given as

$$\phi'_B = \frac{1}{\sqrt{2}}(xyx - yxx), \quad \phi''_B = \frac{1}{\sqrt{6}}(2xxy - xyx - yxx), \quad (30)$$

whereas for $\Lambda(xyz)$ and $\Sigma^o(xyz)$ they are given as

$$\phi'_\Lambda = \frac{1}{2\sqrt{3}}(xzy + zyx - zxy - yzx - 2xyz - 2yxz), \quad \phi''_\Lambda = \frac{1}{2}(zxy + xzy - zyx - yzx), \quad (31)$$

$$\phi'_{\Sigma^o} = \frac{1}{2}(zxy + zyx - xzy - yzx), \quad \phi''_{\Sigma^o} = \frac{1}{2\sqrt{3}}(zyx + zxy + xzy + yzx - 2xyz - 2yxz). \quad (32)$$

For the definition of the spatial wave functions (ψ^s, ψ', ψ'') as well as the definitions of the overlap integrals, we refer the reader to reference [36]. The mixing expressed through the Eq. (26) would be referred to as the “mixed” octet, henceforth we will not distinguish between configuration mixing and the “mixed” octet.

Using the above wavefunctions, one can easily find the spin polarizations for proton, for example

$$\Delta u_{\text{val}} = \cos^2 \phi \left[\frac{4}{3} \right] + \sin^2 \phi \left[\frac{2}{3} \right], \quad \Delta d_{\text{val}} = \cos^2 \phi \left[-\frac{1}{3} \right] + \sin^2 \phi \left[\frac{1}{3} \right], \quad \Delta s_{\text{val}} = 0. \quad (33)$$

These expressions would replace Δq_{val} in Eq. (5) and (21) for calculating the effects of configuration mixing on the valence and the orbital part in the case of proton. Similarly, one can easily find the spin polarization functions for other “mixed” octet members.

The “quark sea” polarizations also gets modified with the inclusion of configuration mixing and can easily be calculated, the details of the calculations in the case of p , Λ and $\Sigma\Lambda$ are given in Appendix A. For the case of proton, these are expressed as

$$\Delta u_{\text{sea}} = -\cos^2 \phi \left[\frac{a}{3}(7 + 4\alpha^2 + \frac{4}{3}\beta^2 + \frac{8}{3}\zeta^2) \right] - \sin^2 \phi \left[\frac{a}{3}(5 + 2\alpha^2 + \frac{2}{3}\beta^2 + \frac{4}{3}\zeta^2) \right], \quad (34)$$

$$\Delta d_{\text{sea}} = -\cos^2 \phi \left[\frac{a}{3}(2 - \alpha^2 - \frac{1}{3}\beta^2 - \frac{2}{3}\zeta^2) \right] - \sin^2 \phi \left[\frac{a}{3}(4 + \alpha^2 + \frac{1}{3}\beta^2 + \frac{2}{3}\zeta^2) \right], \quad (35)$$

$$\Delta s_{\text{sea}} = -a\alpha^2. \quad (36)$$

The “quark sea” spin polarizations for the other octet baryons and transition magnetic moments can similarly be calculated and are presented in Table I.

Configuration mixing due to spin-spin forces does not affect decuplet baryons [10,29], thus the decuplet baryon wave function is given as

$$|B^*\rangle \equiv |56, 0^+\rangle_{N=0} = \chi^s \phi^s \psi^s(0^+), \quad (37)$$

with

$$\chi^s = (\uparrow\uparrow\uparrow). \quad (38)$$

The isospin wave functions for the decuplet baryons of the types $B^*(xxx)$, $B^*(xyx)$ and $B^*(xyz)$ respectively are

$$\phi_{B^*}^s = xxx, \quad \phi_{B^*}^s = \frac{1}{\sqrt{3}}(xyx + yxx + xxy), \quad \phi_{B^*}^s = \frac{1}{\sqrt{6}}(xyz + xzy + yxz + yzx + zxy + zyx), \quad (39)$$

where x , y and z correspond to any of the u , d and s quarks.

IV. INPUTS

To facilitate the understanding of different inputs based on Eq. (4), in Appendix A we have presented the complete expressions for two of the octet baryon magnetic moments p and Λ as well as the $\Sigma\Lambda$ transition magnetic moment, for the case of decuplet baryons we have considered the example of Δ^+ . The other octet and decuplet magnetic moments can similarly be formulated. As is evident from the Appendix, to calculate magnetic moments we need inputs related to χ QM parameters, mixing angle ϕ and quark masses. The parameters a , α , β and ζ of the χ QM, are usually fixed by considering the spin polarization functions Δu , Δd , Δs [2] and related Q^2 independent parameters $\Delta_3 = \Delta u - \Delta d$ and $\Delta_8 = \Delta u + \Delta d - 2\Delta s$ [37] as well as the quark distribution functions including the violation of Gottfried sum rule [26,27] measured through the $\bar{u} - \bar{d}$ asymmetry. In the present analysis we have taken the pion fluctuation parameter a to be 0.1, in accordance with most of the other calculations [13–15]. It has been shown [15] that to fix the violation of Gottfried sum rule [25], we have to consider the relation

$$\bar{u} - \bar{d} = \frac{a}{3}(2\zeta + \beta - 3). \quad (40)$$

In this relation, one immediately finds that in case the value of a is taken to be 0.1 then to reproduce $\bar{u} - \bar{d}$ asymmetry one gets the relation $\zeta = -0.3 - \beta/2$ for the E866 data [26] and $\zeta = -0.7 - \beta/2$ for the case of NMC data [27]. Before carrying out the analysis of χ QM with configuration mixing one has to fix the mixing angle ϕ which in the present case is taken to be $\phi = 20^\circ$ by fitting the neutron charge radius [29,35,38]. After carrying out our analysis regarding the spin polarization functions and using the latest E866 [26] data and the NMC [27] data regarding the $\bar{u} - \bar{d}$ asymmetry, in Table II, we have presented the calculated values of certain phenomenological quantities having implications for χ QM parameters (α and β) with and without configuration mixing. From the table we find that chiral quark model with configuration mixing (χ QM_{gem}) is able to give a fairly good fit to the various spin distribution functions as well as quark distribution functions, in particular, the agreement in the case of Δ_3 , Δ_8 , f_s , f_3/f_8 is quite striking. In the table we have not included the flavor singlet component of the total helicity ($\Delta\Sigma = \Delta u + \Delta d + \Delta s$) which shall be discussed later separately. The χ QM parameters thus found are summarized in Table III and constitute the input for magnetic moment calculations.

The orbital angular momentum contributions are characterized by the parameters of χ QM as well as the masses of the GBs. For evaluating the contribution of pions, we have used its on mass shell value in accordance with several other similar calculations [39]. Similarly, for the other GBs we have considered their on mass shell values, however their contributions are much smaller compared to the pionic contributions.

In accordance with the basic assumptions of χ QM, the constituent quarks are supposed to have only Dirac magnetic moments governed by the respective quark masses. In the absence of any definite guidelines for the constituent quark masses, for the u and d quarks we have used their most widely accepted values in hadron spectroscopy [10,32,36,40,41], for example $M_u = M_d = 330$ MeV. Apart from taking the above quark masses, one has to consider the strange quark mass implied by the various sum rules derived from the spin-spin interactions for different baryons [5,10,29], for example, $\Lambda - N = M_s - M_u$, $(\Sigma^* - \Sigma)/(\Delta - N) = M_u/M_s$ and $(\Xi^* - \Xi)/(\Delta - N) = M_u/M_s$, respectively fix M_s for Λ , Σ and Ξ baryons. These quark masses and corresponding magnetic moments have to be further adjusted by the quark confinement effects [8,9]. In conformity with additivity assumption, the simplest way to incorporate this adjustment [8,9] is to first express M_q in the magnetic moment operator in terms of M_B , the mass of the baryon obtained additively from the quark masses, which then is replaced by $M_B + \Delta M$, ΔM being the mass difference between the experimental value and M_B . This leads to the following adjustments in the quark magnetic moments: $\mu_d = -[1 - (\Delta M/M_B)]\mu_N$, $\mu_s = -M_u/M_s[1 - (\Delta M/M_B)]\mu_N$ and $\mu_u = -2\mu_d$. The baryon magnetic moments calculated after incorporating this effect would be referred to as “mass adjusted”.

Using Eq. (4) and the inputs discussed above as well as the expressions given in Table I, in Table IV we have presented the results of octet magnetic moments without taking any of these as inputs. For a general discussion of the contents of Table IV we refer the readers to Ref [20], however, in the present case we would like to discuss in detail the role of generalized Cheng-Li mechanism, configuration mixing and “mass adjustments” in getting the fit for octet magnetic moments. To this end, one can immediately find that χ QM with generalized Cheng-Li mechanism, however without configuration mixing and “mass adjustments”, consistently improves the predictions of NRQM as well as is able to generate a non zero value of Δ CG. On closer examination of the results, several interesting points pertaining to generalized Cheng-Li mechanism emerge. The total contribution to the magnetic moment is coming from several sources with similar and opposite signs, for example, the orbital is contributing with the same sign as the valence part, whereas the sea is contributing with opposite sign. The sea and orbital contributions are fairly significant as compared to the valence contributions and they cancel in the right direction, for example, the valence contributions of p , Σ^+ and Ξ^0 are higher in magnitude than the experimental value but the sea contribution being higher in magnitude than the orbital contribution reduces the valence contribution leading to a better agreement with data. Similarly, in the case of n , Σ^- and $\Sigma\Lambda$ the valence contribution in magnitude is lower than the experimental value but in these cases the sea contribution is lower than the orbital part so it adds on to the valence contribution again improving agreement with data. Thus, in a very interesting manner, the orbital and sea contributions together add on to the valence contributions leading to better agreement with data as compared to NRQM. This not only endorses the earlier conclusion of Cheng and Li [13] but also suggests that the Cheng-Li mechanism could perhaps provide the dominant dynamics of the constituents in the nonperturbative regime of QCD on which further corrections could be evaluated. To this end, in Table IV, we have presented the results wherein the effects of configuration mixing and “mass adjustments” have been included. As is evident from the table, we have been able to get an excellent fit for almost all the baryons, it is almost perfect for p , Σ^+ , Ξ^0 , $\Sigma\Lambda$ and Δ CG whereas in the other cases the value is reproduced within 5% of data.

In order to study closely the role of configuration mixing on octet magnetic moments, in Table IV we have presented the results with and without mixing, however with the inclusion of “mass adjustments”. As is evident from the table, one finds that the individual magnetic moments show improvements after the inclusion of configuration mixing, particularly in the case of p , n , Σ^+ , Ξ^0 , Λ and $\Sigma\Lambda$ one observes a significant improvement. It may be noted that configuration mixing reduces valence, sea and orbital contributions to the magnetic moments and the results which are generally on the higher side get corrected in the right direction by the inclusion of configuration mixing. This is particularly manifest in the case of Ξ particles, for example, the magnitude of Ξ^0 magnetic moment without configuration mixing is lowered so as to achieve an almost perfect fit, whereas in case of Ξ^- , a difficult case for most of the models, configuration mixing increases the magnitude for better agreement with data. In contrast to general improvement in the case of individual magnetic moments, Δ CG hardly gets affected by configuration mixing. In view of the fact that χ QM with configuration mixing involves baryon wave functions which are perturbed by the spin-spin forces, therefore, in principle one should employ the fully perturbed wave functions of the octet baryons as derived by Isgur *et al.* [10] given in Eq. (25). However, we have found that for the present case the use of “mixed” octet (Eq. (26)) is adequate to reproduce the results of fully perturbed wave function to the desired level of accuracy. One may wonder whether Δ CG could also be reproduced with the variation of mixing angle ϕ . Our calculations in this regard show that variation of ϕ does not lead to any improvement in the magnetic moments as well as Δ CG. The present value of angle ϕ , fixed from the neutron charge radius [29,35,38], seems to be providing the best fit.

It would also perhaps be interesting to find out the implications of configuration mixing for χ QM without “mass adjustments”. Broadly speaking the individual magnetic moments can again be fitted, however Δ CG leaves much to be desired. This can be easily checked from Table V, wherein we have presented these calculations with the NMC data, the E866 based fit follows the same pattern. The value of Δ CG registers a remarkable improvement when effects due to “mass adjustments” alongwith configuration mixing are included. This is not surprising as the large value of Δ CG could come only from the valence quark corrections, duly provided by the “mass adjustments”. It would be desirable to know what level of fit can be achieved without configuration mixing, however with the inclusion of “mass adjustments”. A closer examination of the table immediately brings out that in this case the individual magnetic moments leave much to be desired whereas one is able to reproduce Δ CG, in accordance with our earlier conclusions. It may also be noted that the “mass adjustments” generally lower the various contributions except for the nucleon. In short, we may emphasize that the final fit obtained here cannot be achieved if any of the ingredients, for example, generalized Cheng-Li mechanism, configuration mixing and “mass adjustments, is absent.

For the sake of completeness, as mentioned earlier also, we have presented in Table V the octet magnetic moments when the χ QM parameters are fitted by incorporating NMC data. This table also includes our results wherein magnetic moments have been calculated with configuration mixing however without “mass adjustments”, not included

in Table IV. From the table, one can immediately find out that the basic pattern of results remain the same, however in general the results are lower as compared to the case of E866 data. This is not difficult to understand when one realizes that the contribution of sea polarization in case of E866 and NMC data are quite different. This can be understood easily when one realizes that the sea quark polarization is proportional to the parameter ζ . Because of $|\zeta_{E866}| < |\zeta_{NMC}|$, one can easily understand the corresponding lowering of the magnetic moments in the case of NMC data, however both the calculations are in good agreement with each other.

In Table VI, we have presented the results of the decuplet baryons for the the latest E866 and the NMC data. The calculations of decuplet magnetic moments have been carried out with the same χ QM parameters and quark masses as that of the octet magnetic moments. From the table, it is evident that we have been able to obtain a very good agreement pertaining to the case of Δ^{++} and Ω^- whereas in the case of transition magnetic moment ΔN we obtain a fairly good agreement. In order to compare the present results with other recent similar calculations [14,15], in the table we have included these results also. A closer examination of the decuplet magnetic moments reveals several interesting points which would have bearing on the generalized Cheng-Li mechanism. For example, in the case of Δ^- and Σ^- , because the orbital part dominates over the “quark sea” polarization, the magnetic moments are higher as compared to the results of NRQM and Refs. [14,15]. On the other hand, in the case of Δ^+ and Σ^+ , the “quark sea” polarization dominates over the orbital part as a consequence of which the magnetic moment contribution is more or less the same as that of the results of NRQM as well as those of Refs. [14,15]. In general, one can find that whenever there is an excess of d quarks the orbital part dominates, whereas when we have an excess of u quarks, the “quark sea” polarization dominates. A measurement of these magnetic moments, therefore, would have important implications for the χ QM as well as the Cheng-Li mechanism with its generalization.

While carrying out the fit, as mentioned earlier, the quark masses which have been employed for the calculations correspond to the generally accepted values used for hadron spectroscopic calculations. It may be of interest to study the variation of these masses on the magnetic moments. To this end, in Table VII, we have investigated the effect of varying valence quark masses. As is evident from the table we find that results worsen in both the cases, for example, when they are reduced or increased compared to the ones considered earlier. The violation of CGSR is also fitted best for the generally accepted mass values employed in our calculations. These results remain true for E866 as well as the NMC data. This looks to be surprising as the hadron spectroscopic predictions are known to be somewhat insensitive to the valence quark masses.

While discussing the inputs, we have already seen that χ QM_{gcm} is able to give an excellent fit to the Q^2 independent flavor non-singlet components, for example, Δ_3 and Δ_8 . The flavor singlet component $\Delta\Sigma$ is also known to be having a weak Q^2 dependence [32,42], therefore in principle we should be able to get a good fit to this quantity also. However, in the absence of gluon contribution, expectedly the agreement does not turn out to be as impressive as in the case of flavor non-singlet components. The quark spin distribution functions can be corrected by the inclusion of gluon anomaly [32,42] through

$$\Delta q(Q^2) = \Delta q - \frac{\alpha_s(Q^2)}{2\pi} \Delta g(Q^2), \quad (41)$$

therefore, the flavor singlet component of the total helicity in the χ QM can be expressed as

$$\Delta\Sigma(Q^2) = \Delta\Sigma - \frac{3\alpha_s(Q^2)}{2\pi} \Delta g(Q^2), \quad (42)$$

where $\Delta\Sigma(Q^2)$ and $\Delta q(Q^2)$ are the experimentally measured quantities whereas $\Delta\Sigma$ and Δq correspond to the calculated quantities in the χ QM. Using $\Delta\Sigma(Q^2) = 0.30 \pm 0.06$ [3], $\Delta\Sigma = 0.62$ and $\alpha_s(Q^2 = 5\text{GeV}^2) = 0.287 \pm 0.020$ [19], the gluon polarization, $\Delta g(Q^2)$, comes out to be 2.33. Interestingly, this value comes out to be in fair agreement with certain recent measurements [43] as well as theoretical estimates [44,45]. The effects of the gluon polarization can easily be incorporated into the calculations of spin polarization functions and magnetic moments, without getting into the details, the calculated values of the relevant phenomenological quantities affected by the gluon polarizations are presented in Table VIII. From the table, we find that the present value of Δg improves the results of various quantities, in particular, for Δu , Δd , Δs , $\Delta\Sigma$, μ_n , μ_{Σ^-} , μ_Λ and $\mu_{\Sigma\Lambda}$ the results hardly leave anything to be desired whereas μ_{Ξ^-} , a difficult case in most of the models, also registers a good deal of improvement. The decuplet magnetic moments do not show much change when correction due to Δg are included, for example, in the case of Ω^- , -2.01 changes to -2.04 whereas in the case of Δ^{++} , 5.97 changes to 5.94 . In the absence of experimental data for the other decuplet baryons, we have not included the Δg corrected results in the table.

It may be of interest to emphasize here that the excellent fit achieved for the spin distribution functions, quark distribution functions and hyperon parameters alongwith the magnetic moments as well as the gluon polarization, strongly suggests a deeper significance of the values of the parameters employed, in particular the quark masses and the mixing angle.

To summarize, the input parameters pertaining to the χ QM with and without configuration mixing, have been fixed by carrying out a brief analysis incorporating the latest data pertaining to $\bar{u} - \bar{d}$ asymmetry and spin polarization functions. These parameters of χ QM when used with the generally accepted values of the quark masses M_q , incorporating the “quark sea” contribution as well as its orbital angular momentum through the generalized Cheng-Li mechanism, not only improve the baryon magnetic moments as compared to NRQM but also give a non zero value for Δ CG. The predictions of the χ QM with the generalized Cheng-Li mechanism improve further when effects of configuration mixing and “mass adjustments” due to confinement effects are included, for example, in the case of E866 data we get an excellent fit for the octet magnetic moments and an almost perfect fit for Δ CG. Interestingly, we find that generalized Cheng-Li mechanism coupled with the effects of configuration mixing plays a crucial role in fitting the individual magnetic moments, whereas “mass adjustments” alongwith the generalized Cheng-Li mechanism play an important role in fitting Δ CG. When the above analysis is repeated with the earlier NMC data, a similar level of agreement is obtained however the results in the case of E866 look to be better. Interestingly, we find that the masses $M_u = M_d = 330$ MeV, after corrections due to configuration mixing and “mass adjustments”, provide the best fit for the magnetic moments.

In the case of decuplet baryon magnetic moments, we find a good agreement of Δ^{++} and Ω^- with the experimental data. On comparison of our results with the corresponding results of Song and Linde *et al.*, we find that the measurement of the Δ^+ , Δ^- , Σ^+ , Σ^- would have implications for the Cheng-Li mechanism.

Within χ QM with configuration mixing, when $\Delta q(Q^2)$ is corrected by the inclusion of gluon contribution through axial anomaly [32,42], we not only obtain improvement in the quark spin distribution functions and magnetic moments but also the gluon polarization found in this manner is very much in agreement with certain recent measurements [43] as well as theoretical estimates [44,45].

In conclusion, we would like to state that the success of χ QM with the Cheng-Li mechanism and configuration mixing in achieving an excellent agreement regarding spin distribution functions, quark distribution functions and magnetic moments, strongly suggests that, at leading order, constituent quarks and the weakly interacting Goldstone bosons constitute the appropriate degrees of freedom in the nonperturbative regime of QCD with the weakly interacting gluons (*a la* Manohar and Georgi) providing the first order corrections.

ACKNOWLEDGMENTS

The authors would like to thank S.D. Sharma, M. Randhawa and J.M.S. Rana for a few useful discussions. H.D. would like to thank CSIR, Govt. of India, for financial support and the chairman, Department of Physics, for providing facilities to work in the department.

APPENDIX A

The magnetic moment of a given baryon in χ QM with sea and orbital contributions, following Eq. (4), is given as

$$\mu(B)_{\text{total}} = \mu(B)_{\text{val}} + \mu(B)_{\text{sea}} + \mu(B)_{\text{orbit}}. \quad (\text{A-1})$$

To calculate the valence contribution to the magnetic moment, $\mu(B)_{\text{val}}$, we first express it in terms of valence quark polarizations (Δq_{val}) and the quark magnetic moments (μ_q), for example,

$$\mu(B)_{\text{val}} = \Delta u_{\text{val}} \mu_u + \Delta d_{\text{val}} \mu_d + \Delta s_{\text{val}} \mu_s. \quad (\text{A-2})$$

The quark polarizations can be calculated from the spin structure of a given baryon. Using Eqs. (7) and (26) of the text, the spin structure of a baryon in the “mixed” octet is given as

$$\hat{B} \equiv \langle B | \mathcal{N} | B \rangle = \cos^2 \phi \langle 56, 0^+ | \mathcal{N} | 56, 0^+ \rangle_B + \sin^2 \phi \langle 70, 0^+ | \mathcal{N} | 70, 0^+ \rangle_B. \quad (\text{A-3})$$

For the case of proton, using Eqs. (27) and (28) of the text, we have

$$\langle 56, 0^+ | \mathcal{N} | 56, 0^+ \rangle_p = \frac{5}{3} u_+ + \frac{1}{3} u_- + \frac{1}{3} d_+ + \frac{2}{3} d_-, \quad (\text{A-4})$$

$$\langle 70, 0^+ | \mathcal{N} | 70, 0^+ \rangle_p = \frac{4}{3} u_+ + \frac{2}{3} u_- + \frac{2}{3} d_+ + \frac{1}{3} d_-. \quad (\text{A-5})$$

The valence contribution to the magnetic moment for the proton, $\mu(p)_{\text{val}}$, can be found by using Eqs. (A-2), (A-3), (A-4) and (A-5), for example,

$$\mu(p)_{\text{val}} = \left[\cos^2 \phi \left(\frac{4}{3} \right) + \sin^2 \phi \left(\frac{2}{3} \right) \right] \mu_u + \left[\cos^2 \phi \left(-\frac{1}{3} \right) + \sin^2 \phi \left(\frac{1}{3} \right) \right] \mu_d + [0] \mu_s. \quad (\text{A-6})$$

For the Λ hyperon, we have

$$\langle 56, 0^+ | \mathcal{N} | 56, 0^+ \rangle_\Lambda = \frac{1}{2} u_+ + \frac{1}{2} u_- + \frac{1}{2} d_+ + \frac{1}{2} d_- + 1 s_+ + 0 s_-, \quad (\text{A-7})$$

$$\langle 70, 0^+ | \mathcal{N} | 70, 0^+ \rangle_\Lambda = \frac{2}{3} u_+ + \frac{1}{3} u_- + \frac{2}{3} d_+ + \frac{1}{3} d_- + \frac{2}{3} s_+ + \frac{1}{3} s_-, \quad (\text{A-8})$$

and

$$\mu(\Lambda)_{\text{val}} = \left[\sin^2 \phi \left(\frac{1}{3} \right) \right] \mu_u + \left[\sin^2 \phi \left(\frac{1}{3} \right) \right] \mu_d + \left[\cos^2 \phi(1) + \sin^2 \phi \left(\frac{1}{3} \right) \right] \mu_s. \quad (\text{A-9})$$

Similarly, we can calculate the valence contribution to the magnetic moments for other octet baryons, however the calculation of the transition magnetic moment $\mu(\Sigma\Lambda)$ is somewhat different, for which we have

$$\langle 56, 0^+ | \mathcal{N} | 56, 0^+ \rangle_{\Sigma\Lambda} = \frac{1}{2\sqrt{3}} u_+ - \frac{1}{\sqrt{3}} u_- - \frac{1}{2\sqrt{3}} d_+ + \frac{1}{\sqrt{3}} d_-, \quad (\text{A-10})$$

$$\langle 70, 0^+ | \mathcal{N} | 70, 0^+ \rangle_{\Sigma\Lambda} = \frac{1}{4\sqrt{3}} u_+ + \frac{3}{4\sqrt{3}} u_- - \frac{1}{4\sqrt{3}} d_+ - \frac{3}{4\sqrt{3}} d_-, \quad (\text{A-11})$$

giving

$$\mu(\Sigma\Lambda)_{\text{val}} = -\frac{1}{2\sqrt{3}} \left[\left(\cos^2 \phi \left(-\frac{1}{\sqrt{3}} \right) + \sin^2 \phi \left(-\frac{1}{2\sqrt{3}} \right) \right) - 2 \left(\cos^2 \phi \left(\frac{1}{\sqrt{3}} \right) + \sin^2 \phi \left(\frac{1}{2\sqrt{3}} \right) \right) \right] (\mu_u - \mu_d). \quad (\text{A-12})$$

The “quark sea” contribution to the magnetic moment of a given baryon, $\mu(B)_{\text{sea}}$, can be expressed in terms of the sea quark polarizations (Δq_{sea}) and μ_q as

$$\mu(B)_{\text{sea}} = \Delta u_{\text{sea}} \mu_u + \Delta d_{\text{sea}} \mu_d + \Delta s_{\text{sea}} \mu_s. \quad (\text{A-13})$$

To calculate Δq_{sea} for different quarks in a given baryon, we consider the spin structure of the baryon along with the “quark sea”. Using Eq. (9) of the text and Eqs. (A-3), (A-4) and (A-5), the spin structure of the proton and the associated “quark sea” is given as

$$\begin{aligned} \hat{p} = & \cos^2 \phi \left[\frac{5}{3} (\sum P_u u_+ + |\psi(u_+)|^2) + \frac{1}{3} (\sum P_u u_- + |\psi(u_-)|^2) + \frac{1}{3} (\sum P_d d_+ + |\psi(d_+)|^2) + \frac{2}{3} (\sum P_d d_- + |\psi(d_-)|^2) \right] \\ & + \sin^2 \phi \left[\frac{4}{3} (\sum P_u u_+ + |\psi(u_+)|^2) + \frac{2}{3} (\sum P_u u_- + |\psi(u_-)|^2) + \frac{2}{3} (\sum P_d d_+ + |\psi(d_+)|^2) + \frac{1}{3} (\sum P_d d_- + |\psi(d_-)|^2) \right], \end{aligned} \quad (\text{A-14})$$

where

$$\sum P_u = a \left(\frac{9 + \beta^2 + 2\zeta^2}{6} + \alpha^2 \right) \quad \text{and} \quad |\psi(u_\pm)|^2 = \frac{a}{6} (3 + \beta^2 + 2\zeta^2) u_\mp + a d_\mp + a \alpha^2 s_\mp,$$

$$\sum P_d = a \left(\frac{9 + \beta^2 + 2\zeta^2}{6} + \alpha^2 \right) \quad \text{and} \quad |\psi(d_\pm)|^2 = a u_\mp + \frac{a}{6} (3 + \beta^2 + 2\zeta^2) d_\mp + a \alpha^2 s_\mp,$$

$$\sum P_s = a \left(\frac{2\beta^2 + \zeta^2}{3} + 2\alpha^2 \right) \quad \text{and} \quad |\psi(s_\pm)|^2 = a \alpha^2 u_\mp + a \alpha^2 d_\mp + \frac{a}{3} (2\beta^2 + \zeta^2) s_\mp.$$

Using Eqs. (A-13) and (A-14), the “quark sea” contribution to the magnetic moment for the case of proton is given as

$$\begin{aligned}\mu(p)_{\text{sea}} = & \left[-\cos^2\phi \left(\frac{a}{3}(7 + 4\alpha^2 + \frac{4}{3}\beta^2 + \frac{8}{3}\zeta^2) \right) - \sin^2\phi \left(\frac{a}{3}(5 + 2\alpha^2 + \frac{2}{3}\beta^2 + \frac{4}{3}\zeta^2) \right) \right] \mu_u \\ & + \left[-\cos^2\phi \left(\frac{a}{3}(2 - \alpha^2 - \frac{1}{3}\beta^2 - \frac{2}{3}\zeta^2) \right) - \sin^2\phi \left(\frac{a}{3}(4 + \alpha^2 + \frac{1}{3}\beta^2 + \frac{2}{3}\zeta^2) \right) \right] \mu_d + [-a\alpha^2] \mu_s.\end{aligned}\quad (\text{A-15})$$

Similarly, the spin structure for Λ can be obtained by substituting Eq. (9) in Eqs. (A-7) and (A-8) and is given as

$$\begin{aligned}\hat{\Lambda} = & \cos^2\phi \left[\frac{1}{2} \left(\sum P_u u_+ + |\psi(u_+)|^2 + \sum P_u u_- + |\psi(u_-)|^2 + \sum P_d d_+ + |\psi(d_+)|^2 + \sum P_d d_- + |\psi(d_-)|^2 \right) \right. \\ & + \sum P_s s_+ + |\psi(s_+)|^2 \left. \right] + \sin^2\phi \left[\frac{2}{3} \left(\sum P_u u_+ + |\psi(u_+)|^2 + \sum P_d d_+ + |\psi(d_+)|^2 + \sum P_s s_+ + |\psi(s_+)|^2 \right) \right. \\ & + \frac{1}{3} \left(\sum P_u u_- + |\psi(u_-)|^2 + \sum P_d d_- + |\psi(d_-)|^2 + \sum P_s s_- + |\psi(s_-)|^2 \right) \left. \right].\end{aligned}\quad (\text{A-16})$$

The “quark sea” contribution to the magnetic moment for the case of Λ is given as

$$\begin{aligned}\mu(\Lambda)_{\text{sea}} = & \left[-\cos^2\phi (a\alpha^2) - \sin^2\phi \left(\frac{a}{9}(9 + 6\alpha^2 + \beta^2 + 2\zeta^2) \right) \right] \mu_u + \left[-\cos^2\phi (a\alpha^2) - \sin^2\phi \left(\frac{a}{9}(9 + 6\alpha^2 + \beta^2 + 2\zeta^2) \right) \right] \mu_d \\ & + \left[-\cos^2\phi \left(\frac{a}{3}(6\alpha^2 + 4\beta^2 + 2\zeta^2) \right) - \sin^2\phi \left(\frac{4}{9}a(3\alpha^2 + 2\beta^2 + \zeta^2) \right) \right] \mu_s.\end{aligned}\quad (\text{A-17})$$

Similarly, one can calculate the contribution of the “quark sea” spin polarizations to the magnetic moments of the other baryons and these have been listed in Table I. For the transition magnetic moment $\mu(\Sigma\Lambda)$, the spin structure can be obtained from Eqs. (9), (A-10) and (A-11) and is given as

$$\begin{aligned}\widehat{\Sigma\Lambda} = & \cos^2\phi \left[\frac{1}{2\sqrt{3}} \left(\sum P_u u_+ + |\psi(u_+)|^2 \right) - \frac{1}{\sqrt{3}} \left(\sum P_u u_- + |\psi(u_-)|^2 \right) - \frac{1}{2\sqrt{3}} \left(\sum P_d d_+ + |\psi(d_+)|^2 \right) + \frac{1}{\sqrt{3}} \left(\sum P_d d_- + |\psi(d_-)|^2 \right) \right] \\ & + \sin^2\phi \left[\frac{1}{4\sqrt{3}} \left(\sum P_u u_+ + |\psi(u_+)|^2 \right) + \frac{3}{4\sqrt{3}} \left(\sum P_u u_- + |\psi(u_-)|^2 \right) - \frac{1}{4\sqrt{3}} \left(\sum P_d d_+ + |\psi(d_+)|^2 \right) - \frac{3}{4\sqrt{3}} \left(\sum P_d d_- + |\psi(d_-)|^2 \right) \right],\end{aligned}\quad (\text{A-18})$$

giving the “quark sea” contribution to the transition magnetic moment as

$$\begin{aligned}\mu(\Sigma\Lambda)_{\text{sea}} = & -\frac{1}{2\sqrt{3}} \left[-\cos^2\phi \left(\frac{a}{2\sqrt{3}}(3 + 3\alpha^2 + \beta^2 + 2\zeta^2) \right) + \sin^2\phi \left(\frac{a}{2\sqrt{3}}(1 + \alpha^2 + \frac{1}{3}\beta^2 + \frac{2}{3}\zeta^2) \right) \right. \\ & \left. - 2 \left(\cos^2\phi \left(\frac{a}{2\sqrt{3}}(3 + 3\alpha^2 + \beta^2 + 2\zeta^2) \right) - \sin^2\phi \left(\frac{a}{2\sqrt{3}}(1 + \alpha^2 + \frac{1}{3}\beta^2 + \frac{2}{3}\zeta^2) \right) \right) \right] (\mu_u - \mu_d).\end{aligned}\quad (\text{A-19})$$

For calculating the orbital contribution to the total magnetic moment, one has to use generalized Cheng-Li mechanism expressed in Eq. (21) and for the case of proton and Λ it is given as

$$\mu(p)_{\text{orbit}} = \cos^2\phi \left[\frac{4}{3}[\mu(u_+ \rightarrow)] - \frac{1}{3}[\mu(d_+ \rightarrow)] \right] + \sin^2\phi \left[\frac{2}{3}[\mu(u_+ \rightarrow)] + \frac{1}{3}[\mu(d_+ \rightarrow)] \right], \quad (\text{A-20})$$

$$\mu(\Lambda)_{\text{orbit}} = \cos^2\phi [\mu(s_+ \rightarrow)] + \sin^2\phi \left[\frac{1}{3}[\mu(u_+ \rightarrow)] + \frac{1}{3}[\mu(d_+ \rightarrow)] + \frac{1}{3}[\mu(s_+ \rightarrow)] \right]. \quad (\text{A-21})$$

For the case of $\Sigma\Lambda$, the orbital contribution to the magnetic moment is

$$\mu(\Sigma\Lambda)_{\text{orbit}} = \left[\cos^2\phi \left(\frac{1}{2} \right) + \sin^2\phi \left(\frac{1}{4} \right) \right] ([\mu(u_+ \rightarrow)] - [\mu(d_+ \rightarrow)]). \quad (\text{A-22})$$

Using Eq. (A-1) one can calculate the total magnetic moment of p , Λ and $\Sigma\Lambda$. The magnetic moments of other octet baryons can similarly be calculated.

As an example of the decuplet baryon, we detail below the calculation of magnetic moment of Δ^+ . In the absence of any mixing, the spin structure for Δ^+ , using Eqs. (37) of the text, is given as

$$\langle 56, 0^+ | \mathcal{N} | 56, 0^+ \rangle_{\Delta^+} = 2u_+ + d_+. \quad (\text{A-23})$$

The valence contribution to the total magnetic moment is expressed as

$$\begin{aligned}\mu(\Delta^+)_{\text{val}} &= \Delta u_{\text{val}}\mu_u + \Delta d_{\text{val}}\mu_d + \Delta s_{\text{val}}\mu_s \\ &= 2\mu_u + 1\mu_d + 0\mu_s.\end{aligned}\tag{A-24}$$

The contribution of the “quark sea” to the total magnetic moment in terms of the “quark sea” polarizations and μ_q is expressed as

$$\mu(\Delta^+)_{\text{sea}} = \Delta u_{\text{sea}}\mu_u + \Delta d_{\text{sea}}\mu_d + \Delta s_{\text{sea}}\mu_s.\tag{A-25}$$

By substituting Eq. (9) in Eq. (A-23), we obtain the spin structure of Δ^+ and the associated “quark sea” which is expressed as

$$\hat{\Delta}^+ = 2(\sum P_u u_+ + |\psi(u_+)|^2) + (\sum P_d d_+ + |\psi(d_+)|^2),\tag{A-26}$$

and the “quark sea” contribution to the magnetic moment is consequently given as

$$\mu(\Delta^+)_{\text{sea}} = \left[-a(5 + 2\alpha^2 + \frac{2}{3}\beta^2 + \frac{4}{3}\zeta^2)\right]\mu_u + \left[-a(4 + \alpha^2 + \frac{1}{3}\beta^2 + \frac{2}{3}\zeta^2)\right]\mu_d + [-3a\alpha^2]\mu_s.\tag{A-27}$$

The contribution of the “quark sea” to the magnetic moment of other decuplet baryons can similarly be calculated in terms of the “quark sea” polarizations, the expressions for which are given Table I.

The orbital contribution to the total magnetic moment, as given by Eq. (22), is expressed as

$$\mu(\Delta^+)_{\text{orbit}} = 2[\mu(u_+ \rightarrow)] + [\mu(d_+ \rightarrow)].\tag{A-28}$$

Substituting Eqs. (A-24), (A-27) and (A-28) in Eq. (A-1) we get the total magnetic moment of Δ^+ . We can also calculate the transition magnetic moment $\mu(\Delta N)$ in a similar manner as we have calculated $\mu(\Sigma\Lambda)$.

- [1] J.Ashman *et al.*, Phys. Lett. **206B**, 364 (1988); Nucl. Phys. **B328**, 1 (1990).
- [2] SMC Collaboration, B. Adeva *et al.*, Phys. Lett. **302B**, 533 (1993); P. Adams *et al.*, Phys. Rev. D **56**, 5330 (1997).
- [3] E142 Collaboration, P.L. Anthony *et al.*, Phys. Rev. Lett. **71**, 959 (1993); E143 Collaboration, K. Abe *et al.*, Phys. Rev. Lett. **75**, 391 (1995).
- [4] D.B. Lichtenberg, Z. Phys. C **7**, 143 (1981); *ibid.* **17**, 57 (1983); D.A. Dicus *et al.*, Phys. Lett. **284B**, 384 (1992); L. Brekke, Ann. Phys. (N.Y.) **240**, 400 (1995); J. Franklin, Phys. Rev. D **61**, 098301 (2000) and references therein.
- [5] M. Gupta and N. Kaur, Phys. Rev. D **28**, 534 (1983).
- [6] K. Dannbom, L. Ya. Glozman, C. Helminen, D.O. Riska, Nucl. Phys. **A616**, 555 (1997).
- [7] S. Theberge and A.W. Thomas, Phys. Rev. D **25**, 284 (1982); J. Cohen and H.J. Weber, Phys. Lett. **165B**, 229 (1985).
- [8] Ikuo S. Sogami and Noboru Oh'yamaguchi, Phys. Rev. Lett. **54**, 2295 (1985); Kuang-Ta Chao, Phys. Rev. D **41**, 920 (1990).
- [9] M. Gupta, J. Phys. G **16**, L213 (1990).
- [10] N. Isgur, G. Karl and R. Koniuk, Phys. Rev. Lett. **41**, 1269 (1978); R. Koniuk and N. Isgur, Phys. Rev. D **21**, 1868 (1980); N. Isgur and G. Karl, *ibid.*, 3175 (1980); N. Isgur *et al.*, *ibid.* **35**, 1665 (1987); P. Geiger and N. Isgur, *ibid.* **55**, 299 (1997) and references therein.
- [11] T.P. Cheng and Ling Fong Li, Phys. Rev. Lett. **74**, 2872 (1995).
- [12] T.P. Cheng and Ling Fong Li, Phys. Rev. D **57**, 344 (1998); hep-ph/9709293.
- [13] T.P. Cheng and Ling Fong Li, Phys. Rev. Lett. **80**, 2789 (1998).
- [14] X. Song, J.S. McCarthy and H.J. Weber, Phys. Rev. D **55**, 2624 (1997); X. Song, *ibid* **57**, 4114 (1998).
- [15] J. Linde, T. Ohlsson and Hakan Snellman, Phys. Rev. D **57**, 452 (1998).
- [16] Loyal Durand and Phuoc Ha, Phys. Rev. D **58**, 013010 (1998); Phuoc Ha and Loyal Durand, *ibid*, 093008 (1998).
- [17] J. Franklin, Phys. Rev. D **29**, 2648 (1984); G.Karl, *ibid* **45**, 247 (1992); M.A. Luty, J. March-Russell and M. White, *ibid* **51**, 2332 (1995).
- [18] J. Franklin, Phys. Rev. **182**, 1607 (1969).
- [19] K. Hagiwara *et al.*, Phys. Rev. D **66**, 010001 (2002).
- [20] H. Dahiya and M. Gupta, Phys. Rev. D **66**, 051501(R) (2002).

- [21] S. Weinberg, *Physica A* **96**, 327(1979).
- [22] A. Manohar and H. Georgi, *Nucl. Phys.* **B234**, 189(1984).
- [23] E.J. Eichten, I. Hinchliffe and C. Quigg, *Phys. Rev. D* **45**, 2269(1992).
- [24] The Coleman Glashow sum rule for the baryon magnetic moments is given as $\Delta\text{CG} = \mu_p - \mu_n + \mu_{\Sigma^-} - \mu_{\Sigma^+} + \mu_{\Xi^0} - \mu_{\Xi^-} = 0$. Experimentally $\Delta\text{CG} = 0.49 \pm 0.05$, clearly depicting the violation of CGSR by ten standard deviations.
- [25] K. Gottfried, *Phys. Rev. Lett.* **18**, 1174 (1967).
- [26] E866/NuSea Collaboration, E.A. Hawker *et al.*, *Phys. Rev. Lett.* **80**, 3715 (1998); J.C. Peng *et al.*, *Phys. Rev. D* **58**, 092004 (1998); R. S. Towell *et al.*, *ibid* **64**, 052002 (2001).
- [27] New Muon Collaboration, P. Amaudruz *et al.*, *Phys. Rev. Lett.* **66**, 2712 (1991); M. Arneodo *et al.*, *Phys. Rev. D* **50**, R1 (1994).
- [28] A. De Rujula, H. Georgi and S.L. Glashow, *Phys. Rev. D* **12**, 147 (1975).
- [29] A. Le Yaouanc, L. Oliver, O. Pene and J.C. Raynal, *Phys. Rev. D* **12**, 2137 (1975); *ibid.* **15**, 844 (1977).
- [30] M. Gupta, S.K. Sood and A.N. Mitra, *Phys. Rev. D* **16**, 216 (1977); *ibid.* **19**, 104 (1979); M. Gupta and S. Kanwar, *ibid* **26**, 1194 (1982); P. Nath, M. Gupta and A.K. Prasher, *ibid* **26**, 565 (1982).
- [31] L.Ya. Glozman and D.O. Riska, *Phys. Rep.* **268**, 263 (1996), L.Ya. Glozman, Z. Papp and W. Plessas, *Phys. Lett.* **381B**, 311 (1996).
- [32] T.P. Cheng and Ling Fong Li, hep-ph/9811279.
- [33] Adam P. Szczepaniak and Erie S. Swanson *Phys. Rev. Lett.* **87**, 072001 (2001).
- [34] H. Dahiya and M. Gupta, *Phys. Rev. D* **64**, 014013 (2001).
- [35] P.N. Pandit, M.P. Khanna and M. Gupta, *J. Phys. G* **11**, 683 (1985).
- [36] A. Le Yaouanc *et al.*, *Hadron Transitions in the Quark Model*, Gordon and Breach, 1988.
- [37] J. Ellis and M. Karliner, *Phys. Lett.* **313B**, 131 (1993); **341B**, 397 (1995).
- [38] M. Gupta and A.N. Mitra, *Phys. Rev. D* **18**, 1585 (1978); N. Isgur, G. Karl and D.W.L. Sprung, *ibid* **23**, 163 (1981).
- [39] V. Elias, Mong Tong and M.D. Scadron, *Phys. Rev. D* **40**, 3670 (1989); Duane A. Dicus, Djordje Minic, Ubirajara van Klock and Roberto Vega, *Phys. Lett.* **284**, 384 (1992); Y.B. Dong, K. Shimizu, Amand Faessler and A.J. Buchmann, *J. Phys. G* **25**, 1115 (1999).
- [40] F.E. Close, *An Introduction to Quarks and Partons*, Academic Press, New York, 1979 and references therein.
- [41] J. Franklin, *Phys. Rev.* **172**, 1807 (1968); N. Isgur, *Acta Physica Polonica B* **8**, 1081 (1977); G.E. Brown, M. Rho and V. Vento, *Phys. Lett.* **97B**, 423 (1980).
- [42] A.V. Efremov and O.V. Teryaev, Dubna Report No. JIN-E2-88-287, 1988 (unpublished); G. Altarelli and G. Roos, *Phys. Lett.* **212B**, 391 (1988); R.D. Carlitz, J.D. Collins and A.H. Mueller, *ibid.* **214**, 229 (1988); T. Ohlsson and H. Snellman, *Eur. Phys. J. C* **7**, 501 (1999).
- [43] A. Airapetian *et al.*, *Phys. Rev. Lett.* **84**, 2584 (2000).
- [44] E. Di Salvo, hep-ph/9603286; L. Mankiewicz, G. Piller and A. Saalfeld, *Phys. Lett.* **395B**, 318 (1997); C. Bourrely, F. Buccella, O. Pisanti, P. Santorelli, J. Soffer, *Prog. Theor. Phys.* **99**, 1017 (1998); A. De Roeck, A. Deshpande, V. W. Hughes, J. Lichtenstadt, G. Radcliff, *Eur. Phys. J. C* **6**, 121 (1999); M. Glück, E. Reya, M. Stratmann and W. Vogelsang, *Phys. Rev. D* **63**, 094005 (2001).
- [45] H.-J. Lee, D.-P. Min, B.-Y. Park, M. Rho and V. Vento, *Phys. Lett.* **491B**, 257 (2000).
- [46] A. Baldit *et al.*, NA51 Collaboration, *Phys. Lett.* **253B**, 252 (1994).
- [47] A.O. Bazarko *et al.*, *Z. Phys C* **65**, 189 (1995); J. Grassler, H. Leutwyler and M.E. Saino, *Phys. Lett.* **253B**, 252 (1991); S.J. Dong *et al.*, *Phys. Rev. Lett.* **75**, 2096 (1995).

Baryons	Δu_{sea}	Δd_{sea}	Δs_{sea}
$p(uud)$	$-\cos^2\phi \left[\frac{a}{3}(7+4\alpha^2+\frac{4}{3}\beta^2+\frac{8}{3}\zeta^2) \right]$ $-\sin^2\phi \left[\frac{a}{3}(5+2\alpha^2+\frac{2}{3}\beta^2+\frac{4}{3}\zeta^2) \right]$	$-\cos^2\phi \left[\frac{a}{3}(2-\alpha^2-\frac{1}{3}\beta^2-\frac{2}{3}\zeta^2) \right]$ $-\sin^2\phi \left[\frac{a}{3}(4+\alpha^2+\frac{1}{3}\beta^2+\frac{2}{3}\zeta^2) \right]$	$-a\alpha^2$
$\Sigma^+(u us)$	$-\cos^2\phi \left[\frac{a}{3}(8+3\alpha^2+\frac{4}{3}\beta^2+\frac{8}{3}\zeta^2) \right]$ $-\sin^2\phi \left[\frac{a}{3}(4+3\alpha^2+\frac{2}{3}\beta^2+\frac{4}{3}\zeta^2) \right]$	$-\cos^2\phi \left[\frac{a}{3}(4-\alpha^2) \right]$ $-\sin^2\phi \left[\frac{a}{3}(2+\alpha^2) \right]$	$-\cos^2\phi \left[\frac{a}{3}(2\alpha^2-\frac{4}{3}\beta^2-\frac{2}{3}\zeta^2) \right]$ $-\sin^2\phi \left[\frac{a}{3}(4\alpha^2+\frac{4}{3}\beta^2+\frac{2}{3}\zeta^2) \right]$
$\Xi^o(u ss)$	$-\cos^2\phi \left[\frac{a}{3}(3\alpha^2-2-\frac{1}{3}\beta^2-\frac{2}{3}\zeta^2) \right]$ $-\sin^2\phi \left[\frac{a}{3}(2+3\alpha^2+\frac{1}{3}\beta^2+\frac{2}{3}\zeta^2) \right]$	$-\cos^2\phi \left[\frac{a}{3}(4\alpha^2-1) \right]$ $-\sin^2\phi \left[\frac{a}{3}(1+2\alpha^2) \right]$	$-\cos^2\phi \left[\frac{a}{3}(7\alpha^2+\frac{16}{3}\beta^2+\frac{8}{3}\zeta^2) \right]$ $-\sin^2\phi \left[\frac{a}{3}(5\alpha^2+\frac{8}{3}\beta^2+\frac{4}{3}\zeta^2) \right]$
$\Lambda(u ds)$	$-\cos^2\phi [a\alpha^2]$ $-\sin^2\phi \left[\frac{a}{9}(9+6\alpha^2+\beta^2+2\zeta^2) \right]$	$-\cos^2\phi [a\alpha^2]$ $-\sin^2\phi \left[\frac{a}{9}(9+6\alpha^2+\beta^2+2\zeta^2) \right]$	$-\cos^2\phi \left[\frac{a}{3}(6\alpha^2+4\beta^2+2\zeta^2) \right]$ $-\sin^2\phi \left[\frac{4}{9}a(3\alpha^2+2\beta^2+\zeta^2) \right]$
$\Sigma\Lambda$	$-\cos^2\phi \left[\frac{a}{2\sqrt{3}}(3+3\alpha^2+\beta^2+2\zeta^2) \right]$ $\sin^2\phi \left[\frac{a}{2\sqrt{3}}(1+\alpha^2+\frac{\beta^2}{3}+\frac{2}{3}\zeta^2) \right]$	$\cos^2\phi \left[\frac{a}{2\sqrt{3}}(3+3\alpha^2+\beta^2+2\zeta^2) \right]$ $-\sin^2\phi \left[\frac{a}{2\sqrt{3}}(1+\alpha^2+\frac{\beta^2}{3}+\frac{2}{3}\zeta^2) \right]$	0
$\Delta^{++}(uuu)$	$-a(6+3\alpha^2+\beta^2+2\zeta^2)$	$-3a$	$-3a\alpha^2$
$\Delta^+(uud)$	$-a(5+2\alpha^2+\frac{2}{3}\beta^2+\frac{4}{3}\zeta^2)$	$-a(4+\alpha^2+\frac{1}{3}\beta^2+\frac{2}{3}\zeta^2)$	$-3a\alpha^2$
$\Sigma^{*+}(u us)$	$-a(4+3\alpha^2+\frac{2}{3}\beta^2+\frac{4}{3}\zeta^2)$	$-a(\alpha^2+2)$	$-2a(2\alpha^2+\frac{2}{3}\beta^2+\frac{1}{3}\zeta^2)$
$\Sigma^{*o}(u ds)$	$-a(3+2\alpha^2+\frac{1}{3}\beta^2+\frac{2}{3}\zeta^2)$	$-a(3+2\alpha^2+\frac{1}{3}\beta^2+\frac{2}{3}\zeta^2)$	$-2a(2\alpha^2+\frac{2}{3}\beta^2+\frac{1}{3}\zeta^2)$
$\Xi^{*o}(u ss)$	$-a(2+3\alpha^2+\frac{1}{3}\beta^2+\frac{2}{3}\zeta^2)$	$-a(2\alpha^2+1)$	$-a(5\alpha^2+\frac{8}{3}\beta^2+\frac{4}{3}\zeta^2)$
$\Omega^-(sss)$	$-3a\alpha^2$	$-3a\alpha^2$	$-6a(\alpha^2+\frac{2}{3}\beta^2+\frac{1}{3}\zeta^2)$
ΔN	$-\frac{2}{3\sqrt{6}}(3+3\alpha^2+\beta^2+2\zeta^2)$	$\frac{2}{3\sqrt{6}}(3+3\alpha^2+\beta^2+2\zeta^2)$	0

TABLE I. Sea quark spin polarizations for the “mixed” octet baryons and decuplet baryons in terms of the χ QM parameters a , α , β and ζ as discussed in the text. The spin polarizations for the other baryons can be found from isospin symmetry. The spin structure of the octet baryon B without configuration mixing can be obtained by taking $\phi = 0$.

Parameter	Data	χ QM $\alpha = 0.6, \beta = 0.9$		χ QM $_{gcm}$ $\alpha = 0.4, \beta = 0.7$	
		NMC	E866	NMC	E866
Δu	0.85 ± 0.05 [2]	0.88	0.92	0.91	0.95
Δd	-0.41 ± 0.05 [2]	-0.35	-0.36	-0.33	-0.31
Δs	-0.07 ± 0.05 [2]	-0.05	-0.05	-0.02	-0.02
Δ_3	$1.267 \pm .0035$ [19]	1.23	1.28	1.24	1.26
Δ_8	0.58 ± 0.025 [2]	0.63	0.66	0.61	0.67
$\bar{u} - \bar{d}$	$-0.147 \pm .024$ [27]	0.147	0.12	0.147	0.12
\bar{d}/\bar{u}	$-0.118 \pm .015$ [26]				
	1.96 ± 0.246 [46]	1.89	1.59	1.89	1.59
	1.41 ± 0.146 [26]				
f_s	0.10 ± 0.06 [47]	0.15	0.13	0.07	0.05
f_3/f_8	0.21 ± 0.05 [11]	0.25	0.25	0.21	0.21

TABLE II. χ QM parameters (with and without configuration mixing) obtained after fitting spin and quark distribution functions. χ QM $_{gcm}$ corresponds to the case where the “mixed” nucleon (Eq. (26)) has been used with the mixing angle $\phi = 20^\circ$.

Parameter	ϕ	a	α	β	ζ_{E866}	ζ_{NMC}
Value	20°	0.1	0.4	0.7	$-0.3 - \beta/2$	$-0.7 - \beta/2$

TABLE III. Input values of various parameters used in the analysis.

Octet baryons	Data [19]	NRQM	χ QM				χ QM with mass adjustments				χ QM with mass adjustments and configuration mixing			
			Valence	Sea	Orbital	Total	Valence	Sea	Orbital	Total	Valence	Sea	Orbital	Total
p	2.79 \pm 0.00	2.72	3.00	-0.70	0.54	2.84	3.17	-0.59	0.45	3.03	2.94	-0.55	0.41	2.80
n	-1.91 \pm 0.00	-1.81	-2.00	0.34	-0.41	-2.07	-2.11	0.24	-0.37	-2.24	-1.86	0.20	-0.33	-1.99
Σ^-	-1.16 \pm 0.025	-1.01	-1.12	0.13	-0.29	-1.28	-1.08	0.08	-0.26	-1.26	-1.05	0.07	-0.22	-1.20
Σ^+	2.45 \pm 0.01	2.61	2.88	-0.69	0.45	2.64	2.80	-0.55	0.37	2.62	2.59	-0.50	0.34	2.43
Ξ^0	-1.25 \pm 0.014	-1.41	-1.53	0.37	-0.23	-1.39	-1.53	0.22	-0.16	-1.47	-1.32	0.21	-0.13	-1.24
Ξ^-	-0.65 \pm 0.002	-0.50	-0.53	0.09	-0.06	-0.50	-0.59	0.06	-0.01	-0.54	-0.61	0.06	-0.01	-0.56
Λ	-0.61 \pm 0.004	-0.59	-0.65	0.10	-0.08	-0.63	-0.69	0.05	-0.04	-0.68	-0.59	0.04	-0.04	-0.59
$\Sigma\Lambda$	1.61 \pm 0.08	1.51	1.41	-0.02	0.30	1.69	1.45	-0.03	0.30	1.72	1.37	-0.04	0.26	1.63
Δ CG	0.49 \pm 0.05	0				0.10				0.46				0.48

TABLE IV. Octet baryon magnetic moments in units of μ_N for the latest E866 data.

Octet baryons	Data [19]	NRQM	χ QM				χ QM with configuration mixing				χ QM with mass adjustments and configuration mixing			
			Valence	Sea	Orbital	Total	Valence	Sea	Orbital	Total	Valence	Sea	Orbital	Total
p	2.79 \pm 0.00	2.72	3.00	-0.79	0.53	2.74	2.76	-0.62	0.48	2.62	2.94	-0.65	0.41	2.70
n	-1.91 \pm 0.00	-1.81	-2.00	0.30	-0.29	-1.99	-1.76	0.25	-0.39	-1.90	-1.86	0.27	-0.34	-1.93
Σ^-	-1.16 \pm 0.025	-1.01	-1.12	0.16	-0.30	-1.26	-1.09	0.10	-0.25	-1.24	-1.05	0.14	-0.26	-1.17
Σ^+	2.45 \pm 0.01	2.61	2.88	-0.77	0.43	2.54	2.67	-0.65	0.40	2.42	2.59	-0.59	0.36	2.36
Ξ^0	-1.25 \pm 0.014	-1.41	-1.53	0.45	-0.21	-1.29	-1.32	0.26	-0.16	-1.22	-1.32	0.26	-0.14	-1.20
Ξ^-	-0.65 \pm 0.002	-0.50	-0.53	0.08	-0.01	-0.46	-0.56	0.09	-0.01	-0.48	-0.61	0.09	-0.02	-0.54
Λ	-0.61 \pm 0.004	-0.59	-0.65	0.12	-0.07	-0.60	-0.56	0.07	-0.05	-0.54	-0.59	0.07	-0.05	-0.57
$\Sigma\Lambda$	1.61 \pm 0.08	1.51	1.41	-0.01	0.31	1.71	1.41	-0.01	0.26	1.66	1.37	-0.02	0.26	1.61
Δ CG	0.49 \pm 0.05	0				0.10				0.12				0.44

TABLE V. Octet baryon magnetic moments in units of μ_N for the NMC data.

Decuplet baryons	Data [19]	NRQM	X. Song [14]	Linde <i>et al.</i> [15]	Valence	Sea		Orbital		Total	
						NMC	E866	NMC	E866	NMC	E866
Δ^{++}	$3.7 < \mu_{\Delta^{++}} < 7.5$	5.43	5.55	5.21	6.36	-1.59	-1.31	0.94	0.92	5.71	5.97
Δ^+	-	2.72	2.73	2.45	3.18	-0.94	-0.79	0.38	0.37	2.62	2.76
Δ^0	-	0	-0.09	-0.30	0	-0.28	-0.28	-0.18	-0.18	-0.46	-0.46
Δ^-	-	-2.72	-2.91	-3.06	-3.18	0.37	0.23	-0.74	-0.73	-3.55	-3.68
Σ^{*+}	-	3.02	3.09	2.85	3.24	-0.88	-0.73	0.58	0.56	2.94	3.07
Σ^{*0}	-	0.30	0.27	0.09	0.33	-0.28	-0.26	0.01	0.01	0.06	0.08
Σ^{*-}	-	-2.41	-2.55	-2.66	-2.58	0.32	0.20	-0.54	-0.54	-2.80	-2.92
Ξ^{*0}	-	0.60	0.63	0.49	0.52	-0.27	-0.24	0.21	0.21	0.46	0.49
Ξ^{*-}	-	-2.11	-2.19	-2.27	-2.30	0.31	0.21	-0.35	-0.34	-2.33	-2.43
Ω^-	-2.02 ± 0.005	-1.81	-1.83	-1.87	-2.07	0.30	0.21	-0.14	-0.15	-1.91	-2.01
ΔN	$3.23 \pm 0.10^*$	2.44	-	-	2.60	-0.53	-0.41	0.46	0.44	2.53	2.63

* pertains to the PDG 1994 data.

TABLE VI. Decuplet magnetic moments in units of μ_N for NMC and E866 data.

Octet baryons	Data [19]	NRQM	$M_u, M_d = 310 \text{ MeV}$		$M_u, M_d = 340 \text{ MeV}$		$M_u, M_d = 330 \text{ MeV}$	
			NMC	E866	NMC	E866	NMC	E866
p	2.79 ± 0.00	2.72	2.48	2.60	2.69	2.84	2.70	2.80
n	-1.91 ± 0.00	-1.81	-1.79	-1.88	-1.96	-2.06	-1.93	-1.99
Σ^-	-1.16 ± 0.025	-1.01	-1.16	-1.20	-1.28	-1.32	-1.17	-1.20
Σ^+	2.45 ± 0.01	2.61	2.20	2.31	2.42	2.54	2.36	2.43
Ξ^0	-1.25 ± 0.014	-1.41	-1.10	-1.16	-1.26	-1.32	-1.20	-1.24
Ξ^-	-0.65 ± 0.002	-0.50	-0.48	-0.50	-0.56	-0.59	-0.54	-0.56
Λ	-0.61 ± 0.004	-0.60	-0.54	-0.57	-0.63	-0.64	-0.57	-0.59
$\Sigma\Lambda$	1.61 ± 0.08	1.51	1.53	1.50	1.77	1.75	1.61	1.63
ΔCG	0.49 ± 0.05	0	0.29	0.31	0.25	0.31	0.44	0.48

TABLE VII. Comparison of the results of χQM with the generalized Cheng-Li mechanism, configuration mixing and “mass adjustments” in units of μ_N for different sets of quark masses.

Quantity	Expt value	NRQM	Without gluon polarization		With gluon polarization	
			χQM	χQM_{gcm}	χQM	χQM_{gcm}
Δu	0.85 ± 0.05 [2]	1.33	1.02	0.95	0.91	0.84
Δd	-0.41 ± 0.05 [2]	-0.33	-0.38	-0.31	-0.49	-0.42
Δs	-0.07 ± 0.05 [2]	0	-0.02	-0.02	-0.13	-0.13
$\Delta\Sigma$	0.30 ± 0.06 [3]	1	0.62	0.62	0.29	0.29
μ_p	2.79 ± 0.00 [19]	2.72	3.03	2.80	3.00	2.77
μ_n	-1.91 ± 0.00 [19]	-1.81	-2.24	-1.99	-2.21	-1.96
μ_{Σ^-}	-1.16 ± 0.025 [19]	-1.01	-1.26	-1.20	-1.23	-1.17
μ_{Σ^+}	2.45 ± 0.01 [19]	2.61	2.62	2.43	2.59	2.40
μ_{Ξ^0}	-1.25 ± 0.014 [19]	-1.41	-1.47	-1.24	-1.50	-1.27
μ_{Ξ^-}	-0.65 ± 0.002 [19]	-0.50	-0.54	-0.56	-0.57	-0.59
μ_Λ	-0.61 ± 0.004 [19]	-0.59	-0.68	-0.59	-0.71	-0.62
$\mu_{\Sigma\Lambda}$	1.61 ± 0.08 [19]	1.51	1.72	1.63	1.69	1.60

TABLE VIII. The phenomenological quantities affected by the inclusion of gluon polarization. The magnetic moments are in units of μ_N .